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EFFECT OF SOLID WASTE DUMP ON RIVER WATER QUALITY: A PARADIGM IN A NIGERAN TROPICAL ENVIRONMENT

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ABSTRACT
The proliferation of waste dumps in urban and sub-urban areas in Nigeria has become a growing menace to humans and natural ecosystems. This study tried to investigate the effect of waste dump on Otamiri river water quality located in the south eastern part of Nigeria. This river has served as the main source of water supply to many rural communities downstream. Samples of the water were collected at different points along the river during the dry and the rainy seasons and analyzed following established protocols for water quality analysis. Data collected were analyzed using multivariate statistical techniques. The results showed that the waste dump had significant effect on the river water quality, especially during the rainy season. Some water parameters such as electrical conductivity, total dissolved solids, and biological oxygen demand, recorded increased concentration levels in all seasons. The concentration levels of coliform bacteria were exceptionally high in all seasons (mean: 476.4mg/l), far exceeding the maximum permissible limit of 50mg/l. With the exception of pH and manganese, most of other water parameters correlated with the season. It is recommended that constant monitoring of the Otamiri river water is needed to reduce the incidence of water-borne diseases among the population living downstream. Ultimately, proper management of the dumpsite is urgently required to reduce its nuisance level on the immediate environment.

KEY WORDS: Otamiri river, parameters, pollution, season, waste dump, water quality

INTRODUCTION

The problem of solid waste management in Nigeria has become a complex issue as a result of high population growth, accelerated urbanization and industrialization (Aguwamba 2003). It is estimated that each Nigerian generates about 0.85kg of waste per day totalling about 119 million tons of municipal and industrial waste per annum (Ayatomuno 2004; Cookey 2008). The problem of how to manage these wastes is reaching critical proportion. In the recent past, the present democratic government has gone extra mile to invest in the services of waste management companies especially in urban areas, which has lead to quantum improvements in the level of urban cleanliness. But unfortunately solid waste dumps keep on emerging and proliferating at different parts of the urban landscape. Nkwocha and Emeribe (2008) identified a total of 150 authorized and illegal dumpsites in the urban and suburban areas of the South-East and South-South geopolitical zones of Nigeria. Their results show that most of these dumpsites were usually haphazardly located without careful consideration of environmental and public health. These sites are usually open, subjected to open burning, poorly managed, unsightly and are located at undeveloped plots, farmlands, residential areas, and river banks; and constitute breeding grounds to disease vectors and pathogens, with leachate seeping ceaselessly into the soil (Ngwulaka *et al* 2009). The choice of dumpsites in close proximity to rivers and streams is particularly becoming a major concern that merits special attention. This is essentially because most of these surface water bodies still serve as sources of water supply to many urban and rural communities down-stream (Akhionbare, 2007) and are expected to maintain a certain level of quality for their sustainable use by these populations (Obeta, 2009; Bu *et al* 2010). There is a great need to explore the solid waste-surface water quality paradigm in environmental health studies with the view to developing new strategies for intervention and mitigating some easily preventable diseases (Peace and Mazunder 2007, Sheldon and Smith 1995). Information on water quality and pollution sources is important for implementing sustainable water-use management strategies (Zhou *et al* 2007; Sarkar *et al* 2007). The objective of this study therefore was to investigate whether the closeness of a waste dump to a river in a humid tropical environment will significantly affect its water quality all through the two seasons of the year.

MATERIAL AND METHODS

Study Area

The Otamiri River has its source at Egbu community in Owerri North Local Government Area and passes through Owerri town and other sub-urban and rural communities (Nekede, Ihiagwa, Obinze, Mgbirichi, etc). The area drained by the river is located within the humid tropical region with two distinct climatic seasons, namely, wet and dry seasons. The wet or rainy season runs from April to September, and the dry season from October to March. The annual rainfall fluctuates between 1500mm to 1800mm with most rains falling during the wet season. This phenomenon creates high discharges into the river during the rainy season. Also, temperature fluctuates between 28^0C to 40^0C all year round with high evaporation occurring mostly during the dry season. The river has a mean slope of 38.5% draining about 18700 hectares of land. At Owerri, the river passes through a fast growing neighborhood called New Market. This is mainly a residential area with a high population density, and is made up of predominantly the poor and the middle classes, the greatest generators of refuse in Nigeria (Omuta, 1988). Some commercial activities are also practiced along the streets and major roads bordering the area. However, as a result of poor waste collection system in this neighborhood with an estimated population of 17,310, residents found it most convenient to dump their waste at an undeveloped piece of land, a few meters (32m) from the Otamiri river. Due to available space along the river bank, the Owerri Municipal Council in 2000, approved the site as the official dumpsite for most of solid waste collected from the municipality. Consequently, solid waste has been dumped at this site for more than ten years, on a surface area approximately 11 hectares in size, 6 meters high and totally not compacted and capped (see Fig. I). Nearly 30 tons of commingled wastes are dumped here daily. Waste components include metals (beverage cans, ferrous materials), used papers, rags, plastics and organic materials (food remnants, dead leaves). A large quantity of decaying fruits and vegetables (oranges, tomatoes, cabbages, etc) are dumped at the dumpsite. Other elements with toxic properties (dry lead batteries, spent oils, used carbides, paints and resins) are constantly dumped at the site. As these materials are dumped without any cover materials and are constantly exposed to weather and climatic conditions. During the rainy season, for example, most of these materials are washed into the river after torrential rains. Besides, the organic matter and other soluble contents in the waste dump produce leachate that ceaselessly seep into the soil and the river water. The dump site has become a breeding ground for many birds (vultures), animals (wild pigs, antelopes), disease vectors (mosquitoes, flies, cockroaches) and rodents (rats, rabbits, mice).

Sampling, Sample Collection and Analysis

This research is designed to cover both the dry and rainy seasons for optimum results. Four different sampling points A, B, C and D were identified and samples collected from each of them. Point A was located 400m from the source of the stream at Egbu village near Owerri and served as the control. Sample point B was located at 300m from point A, and about 31m from the dumpsite; while point C was located downstream behind Emmanuel College premises, at about 370m from point B. Finally, the sample collected at point D was a composite sample collected from the river banks around Nekede village, about 310m from sampling point C and at 1m below the water surface for analyzing dissolved oxygen. Water samples were collected from the early hours of the day under asceptic conditions using 200ml screw-capped sterile bottles, properly labeled and then transported to the UNIDO Regional Laboratory, Owerri within 1hr in portables flasks equipped with ice bags. They were then properly analyzed following quality control protocols for water quality analysis as recommended by APHA (1995). These samples were collected both in the dry and in the wet seasons and results were presented in ranges covering these two periods. A total of 24 samples were collected and analyzed. Water quality parameters analyzed include turbidity, color, odor, pH, suspended solids, dissolves solids, hardness, magnesium, calcium, phosphate, chloride, nitrate, and total coliform count. In addition to these physical and chemical parameters, water samples were also subjected to bacteriological analyses. For this specific determination, they were subjected to serial dilution and plated in duplicates by the Pour Plate Method on plate agar OXOID, England. The plates were incubated at 36^{0}C for 24h for bacterial enumeration. The determination of the concentration levels of chemical parameters and trace elements was done using a Unicorn Solar Atomic Absorption Spectrophotometer (AAS). Observations were equally made on the water current and human activities going on along the vicinity of the river banks.

TABLE 1: NAFDAC and WHO drinking water standards

S/N Parameter	NAFDAC	WHO	
		Highest desirable level	Max. permissible level
Turbidity (NTU)	-	5	25
Total Dissolved Solid µs/l	500	500	1500
Temperature (^{0}C)	-	-	40
Electrical Conductivity µs/l	-	-	-
pH	6.5 -8.5	7.0 – 8.5	6.5 – 9.2
Total Alkalinity	100	80	120
Hardness	-	100	500
Chloride mg/l	200	200	400
Nitrate mg/l	-	45	100
Potassium mg/l	10	10	45
Calcium mg/l	75	75	200
Iron mg/l	-	0.03	0.10
Sulfite mg/l	200	200	400
Magnesium mg/l	30	0.5	0.1
E.coli	-	-	-
Zinc mg/l	5	5	15

Source: Adapted from NAFDAC (2001) and WHO (2001)

Statistical Analysis

In the primary analysis, univariate statistics were used to present the results of water quality parameters (mean, range, percentages, standard deviation). The means of samples from various sampling points for each of the seasons were calculated and compared with the National Agency for Food, Drug and Administration (NAFDAC) (2001) and the World Health Organization (WHO) (2001) standards for drinking water (Table 1). Student test of hypothesis was used to determine whether or not there were significant differences between the water quality parameters sampled close to or after the dump and those of the corresponding control water sample. The seasonal variations of the parameters investigated were then analyzed using the correlation coefficient as applied by Shrestha and Kazama (2007). The multivariate analysis of variance was then performed to determine if there were any significant differences among the variables in the two seasons (French *et al*, 2010). The statistical significance was assessed at the 95 percent level, and the analysis was performed using SPSS version 17.0 (SPSS Inc., Chicago, IL, USA).

TABLE 2: Concentrations of Water Quality Parameters for Rainy Season

Parameter	Values from Sampling Stations			
	A	B	C	D
Turbidity (NTU)	6.3	24.3	13.6	32.1
Conductivity (microhms/cm)	28.6	790.2	540.4	112.3
pH at 25^0C	6.4	6.9	6.4	6.8
Total solids (mg/l)	132.6	621.5	387.1	555.8
Suspended solids (mg/l)	116.3	601.1	368.2	520.1
Dissolved solids (mg/l)	16.3	20.4	18.9	35.6
Total hardness (mg/l)	24.3	72.1	35.5	168.2
Calcium hardness (mg/l)	19.7	64.3	30.0	158.2
Magnesium hardness (mg/l)	4.6	7.8	5.5	10.0
Calcium (mg/l)	8.6	45.2	12.2	60.1
Magnesium (mg/l)	1.5	3.8	1.8	3.6
Iron (mg/l)	0.04	0.6	0.5	1.5
Manganese (mg/l)	0.03	0.06	0.03	0.21
Phosphate (mg/l)	0.4	9.2	6.3	10.4
Chloride (mg/l)	20.3	161.6	24.6	184.0
Sulphate (mg/l)	42.6	102.6	50.1	103.8
Nitrate(mg/l)	2.4	8.6	3.8	6.2
Alkalinity (mg/l $CaCO_3$)	8.4	15.1	12.3	18.5
BOD_5	5.8	28.2	11.3	37.9
COD	6.7	37.4	25.9	48.3
Total coliform (mpn/100ml)	12.1	122.1	24.1	140.1

TABLE 3: Concentrations of Water Quality Parameters for Dry Season

Parameter	Values from Sampling Stations			
	A	B	C	D
Turbidity (NTU)	2.8	4.2	3.6	6.1
Conductivity (microhms/cm)	18.6	28.5	24.1	32.0
pH at 27^0C	6.5	6.8	6.6	6.5
Total solids (mg/l)	10.3	15.4	14.6	18.3
Suspended solids (mg/l)	1.3	7.1	4.3	5.2
Dissolved solids (mg/l)	9.0	10.3	10.3	11.1
Total hardness (mg/l)	18.1	70.1	31.6	92.4
Calcium hardness (mg/l)	13.3	41.3	19.5	60.1
Magnesium hardness (mg/l)	4.6	9.2	6.4	9.1
Calcium (mg/l)	10.8	28.9	19.2	25.6
Magnesium (mg/l)	0.8	2.3	0.9	2.8
Iron (mg/l)	0.02	0.9	0.02	0.8
Manganese (mg/l)	0.2	6.1	5.2	7.3
Phosphate (mg/l)	0.2	8.1	5.2	7.3
Chloride (mg/l)	12.1	128.5	120.6	121.0
Sulphate (mg/l)	27.4	86.3	31.2	94.6
Nitrate(mg/l)	0.2	0.8	0.4	1.6
Alkalinity (mg/l $CaCO_3$)	4.1	6.2	4.5	8.1
BOD_5	3.8	14.1	5.3	15.2
COD	5.6	8.4	6.0	12.1
Total coliform (mpn/100ml)	8.4	96.2	14.2	112.1

RESULTS AND DISCUSSION

Results from our observation show that there was increased quantity of suspended particles such as dead leaves, plastic materials, pieces of woods etc, seen floating at sampling points B, C, and D especially during the rainy season when the river regime was at its peak.

There were spatial variations in the mean concentration levels of water quality parameters. During the dry season, values obtained showed little variations among the parameters analyzed with the exception of total hardness, calcium, chloride, sulphate and BOD that recorded considerable increase as their mean values exceeded those obtained at the control point A. (Table 2). The greatest increase was recorded in the concentration level of chloride which increased from 12.1mg/l at sampling point A to 125.5mg/l at sampling point B; 120.6mg/l at sampling point C and 141.0mg/l at sampling point D. Aside the nearness of the stream to the waste dump another factor explaining these progressive increases is high evaporation of the river water. However, during the rainy season, some parameters such as total solids, suspended solids, chloride, sulfate, COD and BOD all experienced considerable increase at all the sampling points especially at sampling point B (Table 3). For example, suspended solids increased from 116.3mg/l at point A to 601mg/l at point B and then decreased to 368.2mg/l at point C. The progression of water conductivity level that increased from 28.6microhms/cm at control point A to790.2microhms/cm at point B (an increase of about 96 percent) reflects the status of inorganic pollution and is a measure of TDS in water (McCutchoen et al 1993; Grasby *et al*, 1997). A comparison between the mean values of the parameters for the two seasons show that total dissolved solids (TDS) in the river water samples especially during the rainy season were exceptionally high (476.4mg/l), far exceeding the NAFDAC and WHO maximum permissible limit of 50mg/l (Tables 4 and 5). This concentration level poses great treat to the health of the local population that uses the river water as a source of water supply. There was a quantum increase in the concentration levels of nitrate, calcium, chloride, and potassium, but did not exceed NAFDAC and WHO standards in the two seasons (Table 6). However, some parameters such as manganese, pH,

TABLE 4. Range, Mean and Standard Deviation of Water Quality Parameters for Rainy Season

Parameter	Range	Mean	Standard Deviation
Turbidity (NTU)	6.3 – 32.1	19.1	19.8
Conductivity (μS)	28.6 – 790.2	367.9	587.8
pH	6.4 – 6.9	6.6	0.5
Total solids (mg/l)	132.6 – 855.8	499.3	537.7
Suspended solids (mg/l)	116.3 – 820.1	476.4	537.7
Dissolved solids (mg/l)	16.3 – 35.6	22.8	15.1
Total hardness (mg/l)	24.3 – 168.2	75.0	113.2
Calcium hardness (mg/l)	19.7 – 158.2	68.1	109.2
Magnesium hardness (mg/l)	4.6 – 10.0	6.9	4.20
Iron (mg/l)	0.04 – 1.5	0.7	1.1
Maganese (mg/l)	0.03 – 0.21	0.1	0.2
Phosphate (mg/l)	0.4 – 10.4	6.6	7.7
Chloride (mg/l)	20.3 – 184.0	97.6	151.2
Sulphate (mg/l)	42.6 – 103.8	74.8	50.0
Nitrate (mg/l)	2.4 – 8.2	5.3	4.6
Alkalinity (mg/l $CaCO_3$)	8.4 – 18.5	13.6	7.42
BOD_5	5.8 – 37.9	20.8	25.7
COD	6.7 – 48.3	29.6	30.8
Total coliform (mpn/100ml)	12.1 – 140.1	74.6	114.0

TABLE 5. Range, Mean and Standard Deviation of Water Quality Parameters for Dry Season

Parameter	Range	Mean	Standard Deviation
Turbidity (NTU)	2.8 – 6.1	4.2	2.9
Conductivity (μS)	18.6 – 32.0	25.8	10.0
pH	6.4 – 6.8	6.6	0.32
Total solids (mg/l)	10.3 – 18.3	14.7	4.3
Suspended solids (mg/l)	1.3 – 7.2	4.5	4.2
Dissolved solids (mg/l)	9.0 – 11.1	10.2	1.51
Total hardness (mg/l)	18.1 – 92.4	53.1	59.3
Calcium hardness (mg/l)	13.3 – 60.1	33.6	37.0
Magnesium hardness (mg/l)	4.6 – 9.1	7.1	3.5
Iron (mg/l)	0.02 – 0.8	0.3	0.7
Maganese (mg/l)	0.02 – 0.8	0.02	0.04
Phosphate (mg/l)	0.2 – 7.3	4.7	5.4
Chloride (mg/l)	12.1 – 141.1	100.6	103.2
Sulphate (mg/l)	27.4 – 94.6	59.9	61.5
Nitrate (mg/l)	0.2- 1.6	0.8	1.1
Alkalinity (mg/l $CaCO_3$)	4.1 – 8.1	5.7	3.2
BOD_5	3.8 – 15.2	9.6	10.2
COD	5.6 – 12.1	8.0	5.2
Total coliform (mpn/100ml)	8.4 -112.1	55.2	89.8

and iron recorded little or no increase during the two periods. Biochemical tests for identification of isolates revealed that the coliforms were *E coli* and *Aerobacter aerogenes.* The most probable numbers of *E coli* per ml of river water samples were 74.6 and 55.2 for rainy and dry seasons respectively. These values corresponded with the high level of BOD recorded in all the samples which actually indicated the presence of microorganisms in them. For example, the values ranged from 3.8mg/l to 15.2 mg/l and exceeded the recommended standard of 0.3mg/l at all the sampling points, including the control sample (3.8mg/l). Most importantly, the total coliform count ranges from 8.4mpn/100ml at point A to 112.1mpn/100ml at point D, far above the recommended standard of 2mpn/100ml. The presence of *E coli* in the river water samples with high concentrations recorded during the rainy season especially at sampling point B, is a good indication of the contribution of the waste dump in increasing the pollution load of the river water. The river water is therefore contaminated with dangerous intestinal pathogens which can cause various diseases of public health importance. The presence of these bacteria makes it dangerous for the river water to be used for domestic purposes, except otherwise treated. The common health problems that may from the presence of these pathogens include diarrhea, typhoid fever, infective hepatitis and some gastro-intestinal infections. The water therefore requires some treatment (chlorination, etc) before use. The values of pH at all the sampling points ranged from 6.6 to 8.5 and were normal. Results obtained on chemical parameters at all the sampling points fell below NAFDAC and WHO Standards. The high concentration of total hardness and calcium at sampling point D may not be totally linked with the waste dump but with the increased anthropogenic activities along the river banks (swimming, bathing, washing). The high seasonal variation in the mean values obtained on some parameters such as dissolved solids, suspended solids, phosphates, nitrates, calcium and iron especially at sampling point B could also be attributed to changes in the intensity of biodegradation within the waste dump in which the resultant compounds are washed into the river through run offs. These results are consistent with findings from other studies which observed that seasonal variations in precipitation, surface run-off and ground water flow strongly affect river discharge and consequently the concentration of chemical constituents of river water (Mtethiwa *et al* 2008; Pejman *et al*, 2009; Bouyacioglu and Gunduz, 2004). The correlation matrix showed that with the exception of pH and manganese, most of the parameters analyzed significantly correlated with the season. These include water conductivity (0.87), total solids (0.72), total coliform (0.70), BOD (0.69) and chloride (0.65). This could also be explained by differences in the intensity of climatic factors operating on the waste dump (temperature, rainfall) as well as the rate of chemical and biological processes operating within the waste dump. Although pollutants entering a river system normally result from many transport pathways including storm water, runoff, discharge from ditches and ground water (Zare Gaziri *et al*, 2011; Ouayang *et al*, 2006; Chang, 2008), the proximity of the waste dump to Otamiri river has certainly shown considerable physical, chemical, and most importantly, biological effects on its water quality. The constant dumping of refuse at the site has equally increased the concentration of organic and inorganic constituents of the river water, even though some still remain within established standards. The fact is that contaminants generated within the waste dump during decomposition of the biodegradable components of the waste enter into the water body affecting its quality and ecological health of the river (Llamas and Bharti, 2001; Okeocha, 2000). There are reported elevated cases of diseases in individuals consuming water polluted by waste dumps including high rates of congenital anomalies (Elliot *et al* 2001; Huang and Carpenter 2006; Malik *et al* 2004).

TABLE 6. Comparison of Mean Values for Both Rainy Season and Dry Season with NAFDAC/WHO Standards

Parameter	Mean Rainy Season	Mean Dry Season	NAFDAC/WHO Standards
Turbidity (NTU)	19.1	4.2	50
Conductivity (μS)	367.9	25.8	100.0
pH	6.6	6.6	6.5 – 8.5
Total solids (mg/l)	499.3	14.7	300
Suspended solids (mg/l)	476.4	4.5	50
Dissolved solids (mg/l)	22.8	10.2	250
Total hardness (mg/l)	75.0	53.1	250
Calcium hardness (mg/l)	68.1	33.6	200
Magnesium hardness (mg/l)	6.9	7.1	30
Iron (mg/l)	0.7	0.3	0.3
Maganese (mg/l)	0.1	0.02	0.1
Phosphate (mg/l)	6.6	4.7	-
Chloride (mg/l)	97.6	100.6	600
Sulphate (mg/l)	74.8	59.9	250
Nitrate (mg/l)	5.3	0.8	40
Alkalinity (mg/l $CaCO_3$)	13.6	5.7	10-40
BOD_5	20.8	9.6	0.3
COD	29.6	8.0	40
Total coliform (mpn/100ml)	74.6	55.2	0-2

CONCLUSION

This study has tried to investigate the effect of waste dump on the nearby Otamiri river. Results show that the waste dump has significant effects on the river water quality, although the mean values of most parameters analyzed fell below NAFDAC and WHO standards for drinking water. The most important finding was the high concentration of coliform bacteria in the river water making it most unfit for domestic consumption. The effect of climatic factors, especially high temperature and rainfall, also contributed significantly in explaining the seasonal variations of water quality parameters. There were more pollution loads from the waste dump during the rainy season than during the dry season mainly because of increased leaching and run off arising from the dump. The case in point demonstrates that proper sitting of waste disposal units is an important part of environmental hygiene and needs to be integrated into total environmental planning in the country. Moreover, unsanitary disposal of waste, not only provides harborage for disease vectors, causes emission of odor and environmental nuisance, but also defaces urban habitations and particularly pollutes nearby surface water. The problem of Otamiri river water quality arising from its proximity to the waste dump may be more widespread than this study was able to recognize due to certain limitations of the study. More extensive surveys are needed to monitor the quality of the river water in order to reduce the level of water-borne diseases that may arise from consuming it, especially by the local population downstream. Ultimately, proper management of the dumpsite is required, such as its upgrading to a sanitary landfill, so as to reduce its level of nuisance on its immediate environment.

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